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REVIEW ARTICLE

Approach to Urinary Diversion in the Surgical Patient

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Major surgical procedures may remove part or all of the bladder and make an incontinent or continent urinary diversion appropriate. Preoperative consideration must be given to 1) the stoma and its position, 2) the catheterizable channel, 3) the urinary continence mechanism, and 4) the substitute bladder reservoir. Complete bowel preparation and broad-spectrum antibiotics are desirable. The patient's motivation for taking care of a continent urinary diversion is important, since lifelong catheterization and mucous irrigation may be necessary. The status of the native bladder outlet and urinary sphincter is important in cases in which an orthotopic continent urinary diversion is considered. Preoperative evaluation by a stoma therapist is invaluable. Adequate urinary drainage is important in the immediate postoperative period. Patients with urinary diversions must be followed lifelong to rule out asymptomatic deterioration of their upper urinary tracts and to check for potential metabolic and nutritional problems.
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OVERVIEW

In 1852, Simon [1] reported the first urinary diversion through the creation of ureterosigmoidostomies in a patient with bladder exstrophy. The ureterosigmoidostomy was popular in the first half of the 20th century, however, a high incidence of pyelonephritis, metabolic abnormalities, and malignancy has gradually led to its replacement by other techniques. In 1950, Bricker [2] reported his experience with the ileal conduit incontinent urinary diversion. This operation is simple and reliable and has become the most common form of urinary diversion. At the same time that Bricker described the ileal conduit, Gilchrist et al. [3] described a urinary diversion in which a continent catheterizable neobladder was constructed. The neobladder operation is more complex and has a higher complication rate, but it is desirable for the motivated patient with good functional status to avoid the external urine collection bag. Today there are hundreds of combinations of stoma, catheterizable channel, continence mechanism, and urinary reservoir. Our primary goal is to describe these 4 components for use in reconstruction of the urinary tract after its partial or total ablation and highlight some of the advantages and disadvantages of the major techniques.

STOMA

Nothing is more important to the patient than the external stoma that he or she lives with on a daily basis. Given a choice, most adults with normal genitourinary sensation prefer their native urethras for catheterization in the event that they are not able to empty their bladders due to neurologic disease or surgical trauma. Involve-

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ment of an enterostomal therapist is crucial preoperatively if one is considering creation of a cutaneous catheterizable stoma for urinary diversion. The therapist examines the patient in a supine, sitting, and standing position and also has the patient in their daily attire. This is helpful in finding the best place to position a stoma away from enfoldings of fat, beltlines, overhanging pannus, and scar tissue. During an operation in the supine position, the ability to recognize these functional characteristics of the abdominal wall are lost. The most common stoma sites are the right and left lower quadrants. The umbilicus has also become popular in the last decade [4]. The perineum can also be a site for stomal placement in select patients, particularly when the penile urethra has been destroyed or rendered noncatheterizable.

Another major distinction that needs to be determined preoperatively is the creation of a continent or incontinent stoma. The incontinent stoma has the advantage of not requiring catheterization, draining urine continuously, and greater resistance to stomal stenosis. The continent catheterizable stoma has advantages of being harder to detect, smaller, and lacking the need for a urinary collection bag. The ureterosigmoidostomy employs the anal sphincter as the continence mechanism. If this operation is considered, a preoperative enema is given and the patient asked to hold it for 30 min while doing his normal daily activities. If he or she is able to perform this task, then it is likely that urinary continence will be achieved postoperatively. Over the last several years, the orthotopic continent urinary diversion to the urethra has been used in males with good success and recently has been shown to have good success in females as well [5].

The ileal conduit stoma is generally situated in the right lower quadrant, and a healthy rosebud allows proper fitting of the appliance and easier care of the skin. When 2 stomas are being considered, it is best to place them at different horizontal levels on the abdominal wall, in case one or both of them require additional stabilization with the use of a belt. A barrier cream is applied around the stoma after the skin is cleaned, and a new bag is applied once or twice a week. If the stoma is more flush with the abdominal wall, the bag may need to be changed on a daily basis. Emptying the bag is easier for the patient or caretaker than performing catheterizations, and preoperative discussion of the motivation and ability of who will be performing this task is important. The quality of life for an incontinent stoma approaches that of the continent stoma, although patient comfort with the stoma, the diagnosis, psychological and employment status, and the ability to cope with the complications also need to be considered [6].

CATHETERIZABLE CHANNEL

When the native urethra is both available and readily catheterizable, it should always be considered as the first choice for a continent catheterizable channel. In its absence, the appendix is the most reliable continent catheterizable channel in children and younger adults [7]. When the appendix has been removed or is diseased, an ileal or colonic segment can be tapered. The stomach, other defunctionalized bowel segments, the ureter, and the bladder itself can be fashioned into a tube for urinary catheterization and evacuation of urine for the continent diversion [8]. It is advantageous to have a continent catheterizable channel that has constant availability, uses minimal bowel, is simple to employ, is mobile, has no staples, is continent, and is easy to catheterize. The transverse retubularized ileum is felt to have many of these advantages. A 2-cm ileal segment is excised with its blood supply and the bowel wall opened longitudinally about 1 cm from the mesentery. The resulting rectangle is retubularized over a 14 French catheter in transverse direction so that the longer portion of the tube (away from the mesentery) is reimplanted into the native bladder, the augmented bladder, or an intestinal reservoir. The shorter portion of the tube (closer to the mesentery) is used to form the stoma. Success rates of 81% in terms of continence and ease of catheterization have been achieved in preliminary series, and this is a second line procedure if the appendix is not available for the continent catheterizable channel [9]. For any of the catheterizable continent channels and stomas, the patient must be comfortable with the technique of clean intermittent catheterization approximately every 4 hr as originally described by Lapides [10]. Depending on the size of the catheterizable channel, catheters from 8 to 16 French may be used. It is desirable to have a catheterizable channel of approximately 14 French caliber in order to be able to irrigate mucous, blood clots, and proteinacious debris from the native, augmented, or neobladder.

CONTINENCE MECHANISM

The most reliable type of continence mechanism created surgically is the flap valve. This is constructed by reimplanting the continent catheterizable channel between the detrusor muscle and mucosa for the native or augmented bladder or between the colonic mucosa and colonic muscle in the case of a colonic augmentation and neobladder. Modification of the flap valve can be made by incising the tenia of the cecum and imbricating the cecum over the appendix so as to create a submucosal tunnel. In general, the length of the tunnel should be 3 to 5 times the width of the tunnel to achieve a continent flap valve (rule of Paquin) [11]. If the bladder wall is quite thickened from inflammation or neurogenic disease, a shorter tunnel length can be used. The trigone and posterior wall of the bladder is fixed in the pelvis and provides more appropriate support for the continent catheterizable channel than the dome of the bladder or an augmentation. Thus, whenever part of the bladder can be

preserved, it is advantageous to have it for reimplantation of both the ureters if necessary and also the continent catheterizable channel when this is used. The Mitrofanoff principle of reimplanting the appendix as the catheterizable continent channel into the bladder has greatly simplified the parts of urinary reconstruction over the last 2 decades [12]. The basic mechanism behind the flap valve is that as the bladder or neobladder fills up, the continent catheterizable channel is compressed between the mucosa and muscular backing of the bladder or reservoir so that the fuller the bladder becomes, the more compression there is and the less chance of any urine leaking through the catheterizable channel. The flap valve cannot be created using the small intestine because there is no well-defined plane between the mucosa and the submucosa and muscle. The stomach is particularly good for creating a flap valve since its muscular wall is thick, its mucosa is thick, and blood supply is quite dependable, although it does require a more extended midline incision for mobilization into the pelvis on either the right or left gastroepiploic artery.

The nipple valve has been used by Koch et al. [13] and has at least a 15% revision rate in skilled hands. The basic mechanism of a nipple valve is that the continent catheterizable channel is extended into the lumen of the bladder or reservoir and fixed into position. When the urine fills the bladder, it compresses the continent catheterizable channel circumferentially throughout its length of nipple in the bladder, thus preventing leakage. Permanent suture or staples cannot be used in the urinary tract due to stone formation, so over time, many of the nipple valves tend to break down. The nipple valve is particularly useful when the small bowel is used for neobladder creation, since it does not provide an effective flap valve mechanism for the continent catheterizable channel.

The Benchekroun procedure is used to intussuscept the ileum into itself so that as the bladder is filled, the urine compresses the intussuscepted segment so as to achieve continence [14]. This procedure is suitable for patients after removal of the bladder and colon for either benign or malignant disease.

RESERVOIR

The bladder as a reservoir must be able to fill and empty approximately every 4 hr with storage of urine at a low pressure to preserve the upper urinary tracts and guard against incontinence since the sphincter is relying on low-pressure bladder urine storage. Before embarking on any urologic reconstruction, a solid understanding of the anatomy of the kidneys, ureters, bladder, sphincter, and urethra is essential. A creatinine clearance of at least 30 ml/min is generally suggested. Otherwise, metabolic derangements may be severe. Both small and large intestine produce hyperchloremic metabolic acidosis when placed in continuity with the urinary tract. In patients with poor renal function, interposing the stomach should be considered to offset the acidosis. This is termed a balanced augmentation, in which the bladder is augmented with both intestine and stomach so that the mucous production of the intestine tends to be counteracted by the acid of the stomach, and the acidosis produced by the intestine is also counteracted by the stomach. The functional status of the bladder and sphincter mechanism must also be studied preoperatively with urodynamics. From the patient's standpoint, it is most important that he or she accept the responsibility for diligent irrigation of his or her mucous if intestine is used in continuity with the bladder, since bladder rupture with either an augmented bladder or neobladder is possible if a mucous plug prevents drainage.

The advantages of using the stomach for either bladder augmentation or replacement is that its vascular supply is very dependable, it is easy to create a flap valve for both the ureters and the continent catheterizable channel, and it is almost always available. Disadvantages of the stomach include the production of acid that may result in the hematuria dysuria syndrome [8]. The ileum can be used for urinary reconstruction, and it is often readily available, has a dependable blood supply, is close to the pelvis, and provides a lower pressure reservoir than the colon. Disadvantages of the ileum are that it may have been involved after radiation therapy for a pelvic malignancy and may have other underlying disease processes. The jejunum is to be avoided because it results in hypochloremic, hyponatremic, and hyperkalemic metabolic acidosis, and electrolyte abnormalities are more difficult to correct than in other bowel segments. Advantages of the colon are its larger diameter and for the sigmoid colon, its proximity to the bladder. The colon does tend to make more mucous than the ileum when interposed in the urinary tract. It is wise to avoid the use of the ileocecal valve, since in patients with neurogenic bowel, this may be part of their continence mechanism and diarrhea may result from its removal. A good mechanical bowel preparation with oral antibiotics is important. If one is uncomfortable with the patient from a psychological, metabolic, bowel preparation, or medical standpoint, it is best to postpone the surgery. If reconstruction is done in an unexpected fashion during resection of a pelvic mass, it is always possible to leave a Foley urethral drainage catheter, suprapubic tube, or bilateral nephrostomy tubes in severe cases.

The more original urinary tract that can be maintained, the better. If the patient can use his or her own urethra and sphincter mechanism, a bladder augmentation can be performed with even a small amount of bladder left after resection for benign or malignant disease. Most patients will not be able to urinate after a bladder augmentation, although some patients with a coordinated sphincter can do the Valsalva maneuver to empty their bladders against

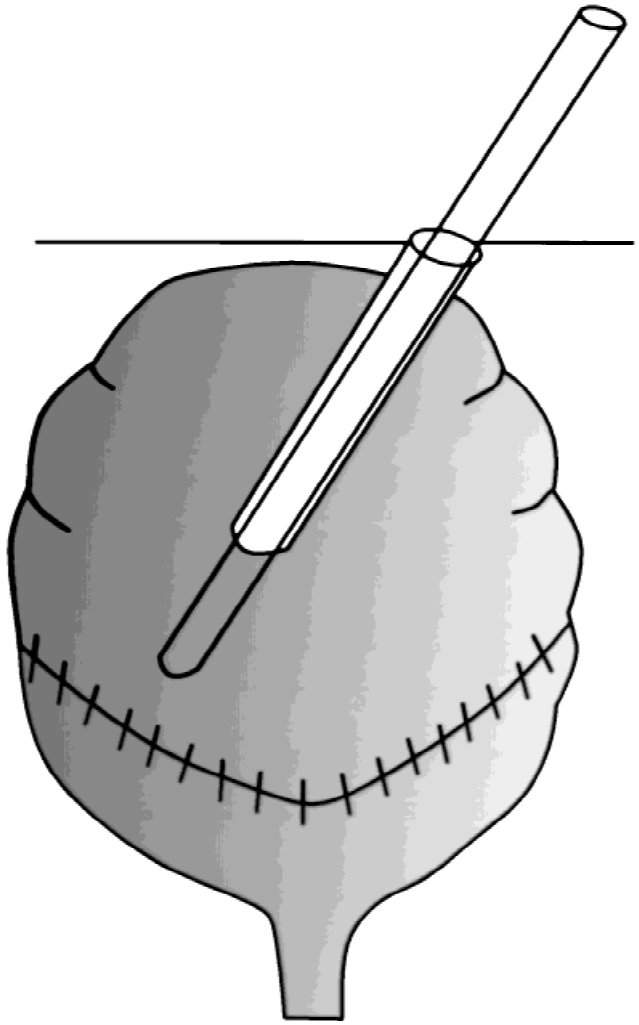

Fig. 1. Colocystoplasty with continent catheterizable channel to umbilicus: The bladder is augmented with colon. The appendix or a tube of reconfigured ileum is reimplanted into the colon between the colonic mucosa and muscle (or alternatively between the bladder mucosa and muscle). This tube is anastomosed to the skin as a continent catheterizable stoma.

a low outlet resistance. The principles of augmentation require a good blood supply with detubularization of the bowel segment so as to decrease its peristaltic pressure while facilitating low-pressure urine storage, thereby protecting the patient from incontinence and upper urinary tract deterioration (Fig. 1).

The neobladder is formed by surgically constructing a bladder from intestine or stomach when the bladder is completely removed for benign or malignant disease. There are dozens of types of neobladders, and I am suggesting that none of them is perfect for all patients. It is best to avoid diseased or irradiated bowel or a bowel segment in short supply for the individual patient. It is also suggested to leave the terminal ileum in place for nutritional reasons. The Indiana pouch is one type of continent urinary diversion that has achieved popularity (Fig. 2) [15]. This type of intestinal urinary diversion uses the right hemicolon, which is detubularized and reconfigured into more of a spherical configuration with the efferent limb being the ileum as the continent catheterizable channel to either the right lower quadrant or the umbilicus. Neobladders can also be anastomosed directly to the urethra if the urethra and sphincter mechanism are intact and functional.

The ileal conduit has been used in the last 50 years, and a large experience has been accumulated [16]. The colon conduit has been used extensively as well [17]. The ileal conduit urinary diversion is created by isolating a 10-cm ileal segment, anastomosing it to the right lower quadrant abdominal wall, and reimplanting the ureters into its butt end (Fig. 3). Long-term complications of ileal conduit urinary diversion include delayed sequelae of intestinal surgery, ureteroileal stenosis, elongation and subsequent failure of the ileal conduit to appropriately propel urine, and upper-tract deterioration from other causes. Some feel the advantage of a colon conduit is that it allows a nonrefluxing ureterocolonic anastomosis. It is also possible to undivert an ileal conduit into a continent urinary diversion if the patient's functional, metabolic, medical, and psychological status improve. The great advantage of the ileal conduit is its simplicity, decreased incidence of revision surgery, and easier postoperative care. In cases in which urinary diversion is being done and was not expected preoperatively, it would be the preferred method.

COMPLICATIONS OF URINARY DIVERSION

Urinary leaks, ureteral strictures, pyelonephritis, incontinence, difficulty in catheterizing the continent urinary diversion, stones, short bowel syndrome, and malignancy are some of the possible complications of urinary diversion (Table I). These can occur with interposition of any bowel segment into the urinary tract and are not limited simply to the neobladder construction.

If the bowel segment is not sufficiently detubularized to create a more spherical configuration, the motor activity of the bowel can produce increased pressures that may be transmitted to either the upper urinary tracts as renal deterioration or to the bladder outlet as urinary incontinence. Altered sensorium can occur as a consequence of altered ammonia metabolism; coma can occur in patients with urinary intestinal diversion in a setting of liver disease. Methotrexate chemotherapy has produced toxicity in patients with intestinal urinary diversions, and good drainage of the ileal conduit or intestinal pouch is essential to prevent methotrexate toxicity. Other drugs or their metabolites can be absorbed by the bowel mucosa after being excreted in the urine. The incidence of cancer developing in a patient with ureterosigmoidoscopy is approximately 10% [18]. The average delay in presentation from the time of urinary diversion is 20 years. These

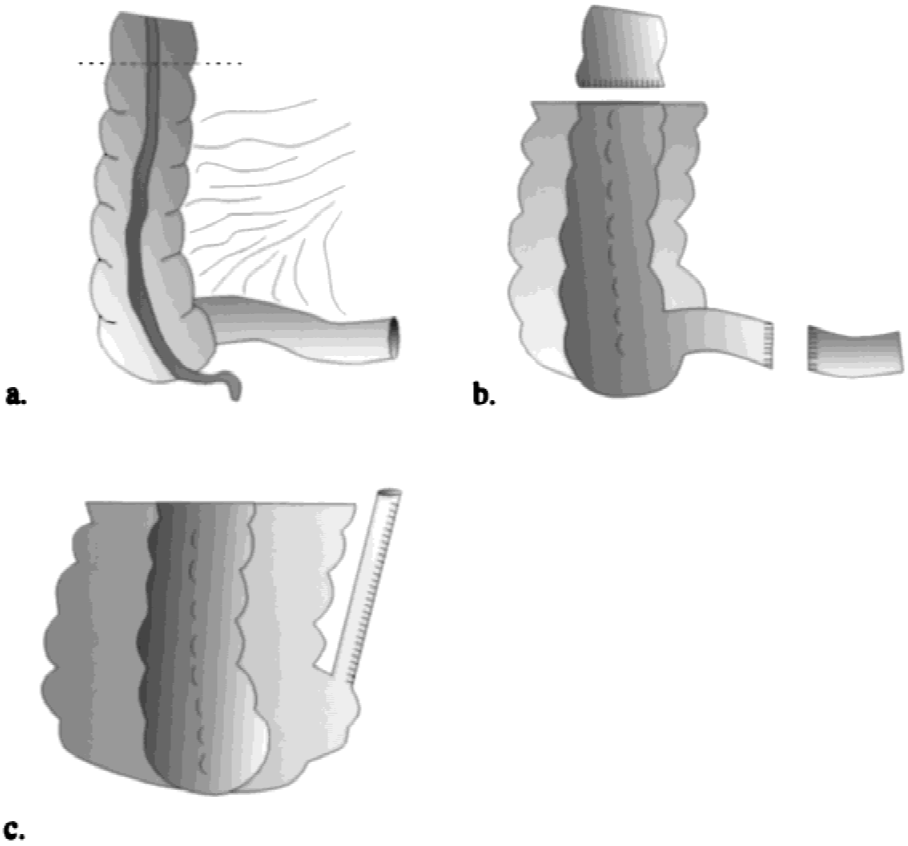

Fig. 2. Continent urinary diversion. The Indiana pouch is made by detubularizing the right hemicolon **(a)** and reconfiguring it into a more spherical structure with its blood supply intact **(b)**. The efferent limb **(c)** is tapered ileum and may be brought out to the umbilicus or right-lower quadrant as a continent catheterizable channel.

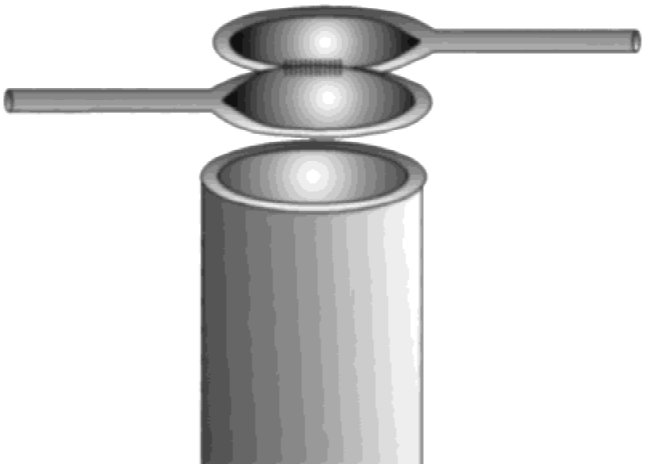

Fig. 3. Ileal conduit: The ureters are spatulated and anastomosed side-to-side before being anastomosed to the butt end of the ileal conduit.

TABLE I. Metabolic and Nutritional Problems Associated With Urinary Diversion

Bowel segment	Problem
Stomach	Hypochloremic metabolic alkalosis
Jejunum	Hyperkalemic, hypochloremic, hyponatremic metabolic acidosis
Ileum	Hyperchloremic metabolic acidosis, malabsorption of bile salts and vitamin B-12 (anemia)
Colon	Hyperchloremic metabolic acidosis

tumors include both adenocarcinomas and transitional cell carcinomas. The same risk exists with any type of urinary diversion or augmentation of the bladder with intestine, and surveillance with urinary cytology, cystoscopy or both is indicated chronically for these patients. Intestinal urinary diversion can also be used in patients before or following renal transplants, however, a multidisciplinary approach to these patients is most important [19].

Any urinary incontinence needs to be evaluated fully to determine whether it is due to the bladder reservoir, the flap valve mechanism, or care of the diversion. Better techniques of stoma creation have resulted in a <10% surgical revision rate [20]. Prolapse around an ileal conduit stoma or stomal stenosis or retrusion can also occur, particularly in the obese patient. For such patients, the

Turnbull stoma may be more appropriate for the ileal or colon conduit urinary diversion.

CONCLUSION

Preoperative evaluation of the anatomy and function of the kidneys, ureters, bladder, sphincter mechanism, and urethra is essential to urinary diversion. Even a small amount of native bladder with an intact sphincter mechanism can be used to reconstruct new bladder using intestine. Patient motivation and evaluation by an enterostomal therapist are very important in determining whether a continent or incontinent urinary diversion is done. Given the known metabolic and nutritional problems and potential for malignancy, any patient with urinary diversion should be followed chronically. The best type of urinary diversion to perform is multifactorial and depends on both the patient's and surgeon's comfort level with the procedure. Patients free from diapers are often most grateful, and a long-term relationship with patients with urinary diversion is very rewarding.

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